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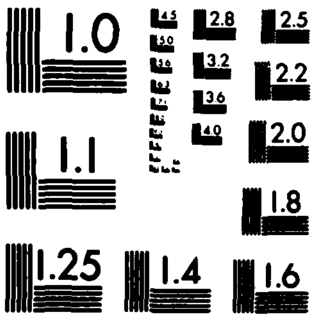

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On the Filamental Quenching of the Current-Driven Ion-Cyclotron Instability

by

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ABSTRACT

Experimental evidence is presented on the effect of the finite width of the current channel for the excitation of the current-driven ion-cyclotron instability. The results are in agreement with the non-local theory of Bakshi, Ganguli, and Palmadesso.

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Experimental evidence is presented on the effect of the finite width of the current channel for the excitation of the current-driven ion-cyclotron instability. The results are in agreement with the nonlocal theory of Bakshi, Ganguli, and Palmadesso.

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Since their discovery over two decades ago,[1] ion-cyclotron waves have been an area of active research in the laboratory,[2] in the ionosphere-magnetosphere,[3] and in the solar corona.[4] The current-driven ion-cyclotron wave instability received its first theoretical treatment in the (local) theory of Drummond and Rosenbluth,[5] appropriate to a uniform, magnetized plasma, without magnetic shear, in which electrons drift along $\underline{B}$ field lines with the same drift velocity, $\underline{v}_D$, at all points in the plasma. Their treatment, however, could not allow, among other things, for the effect that the finite width of the current channel of most laboratory experiments has on the excitation of the instability. This has been considered in the nonlocal theories of, e.g., Ganguli and Bakshi[6] and Bakshi, Ganguli, and Palmadesso.[7] They find that if the width of the current channel is reduced to just a few ion Larmor radii, the instability is completely quenched. They refer to this phenomenon as filamental quenching.[7] Indications of the presence of this phenomenon have been available since the first laboratory experiments on the ion-cyclotron wave instability and, more recently, from, e.g., the work of Sato.[8]

Here we report on a systematic test of the filamental quenching effect, performed on the single-ended Iowa Q-machine. A schematic diagram of the device is shown in Fig. 1(a). Plasma is produced by surface ionization of cesium atoms on a hot (~ 2200 K) tantalum plate 6 cm in diameter and is confined radially by a magnetic field of up to ~ 7 kG. The magnetic field is nonhomogeneous and varies along the

axis of the device into the end chamber, as shown in Fig. 1(b). The ion-cyclotron wave instability is excited, in the usual manner, by drawing current to a metallic disk moveable along the axis of the device, and is detected either in the current oscillations of the disk itself or by means of various (axially and radially moveable) Langmuir probes.

Figure 2 is a plot of the oscillation frequency versus disk position, as detected by the exciter disk or by a probe. The local ion-cyclotron frequency is also shown for comparison. The arrow indicates the location at which, for the particular conditions of Fig. 2, excitation of the fundamental mode ceases. By performing measurements similar to those of Fig. 2, but with various disk diameters and different currents in the magnet coils, we have been able to obtain the diagram shown in Fig. 3. Here the disk radius, r_D, is plotted as a function of r_i^*, the ion Larmor radius at the location of the disk, for which the instability is quenched. The line $r_D = r_i^*$ is also shown.

Evidently, the filamental quenching operates at widths of the current channel comparable to the local Larmor radius, in agreement with the conclusions of Bakshi, Ganguli, and Palmadesso[6] (see, e.g., their Fig. 1). The small departure from the $r_D = r_i^*$ line for the 1.27 cm disk is most likely related to the large density perturbation introduced by this large disk.

Acknowledgments

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Figure Captions

Fig. 1. (a) Schematic cross-sectional view of the Iowa Q-machine. (b) Axial variation of the B_z field in the region near and into the end chamber. For this case a coil current of 160 A produced a field B_o = 1170 G in the center of the main chamber. The arrow indictes the Z = 0 position in parts (a) and (b). Electrostatic ion-cyclotron waves are produced by applying an appropriate bias to the axially moveable excitation disk, and are detected either in the disk current or by various Langmuir probes.

Fig. 2. Oscillation frequency versus exciter disk (0.64 cm radius) position (x). Oscillation frequency detected by a fixed Langmuir probe in the center of the main chamber, Z = -47.5 cm (•). The arrow indicates the Z position at which excitation of the fundamental mode ceases. The solid line is the local ion-cyclotron frequency.

Fig. 3. Plot of exciter disk radius, r_D, versus r_i^*, the ion gyroradius at the location of the disk for which the instability is quenched, for various magnet coil currents between 300 A and 800 A. The exciter disk radii used were: 0.32 cm, 0.64 cm, 0.79 cm, 0.95 cm, and 1.27 cm. The solid line is the line $r_D = r_i^*$.

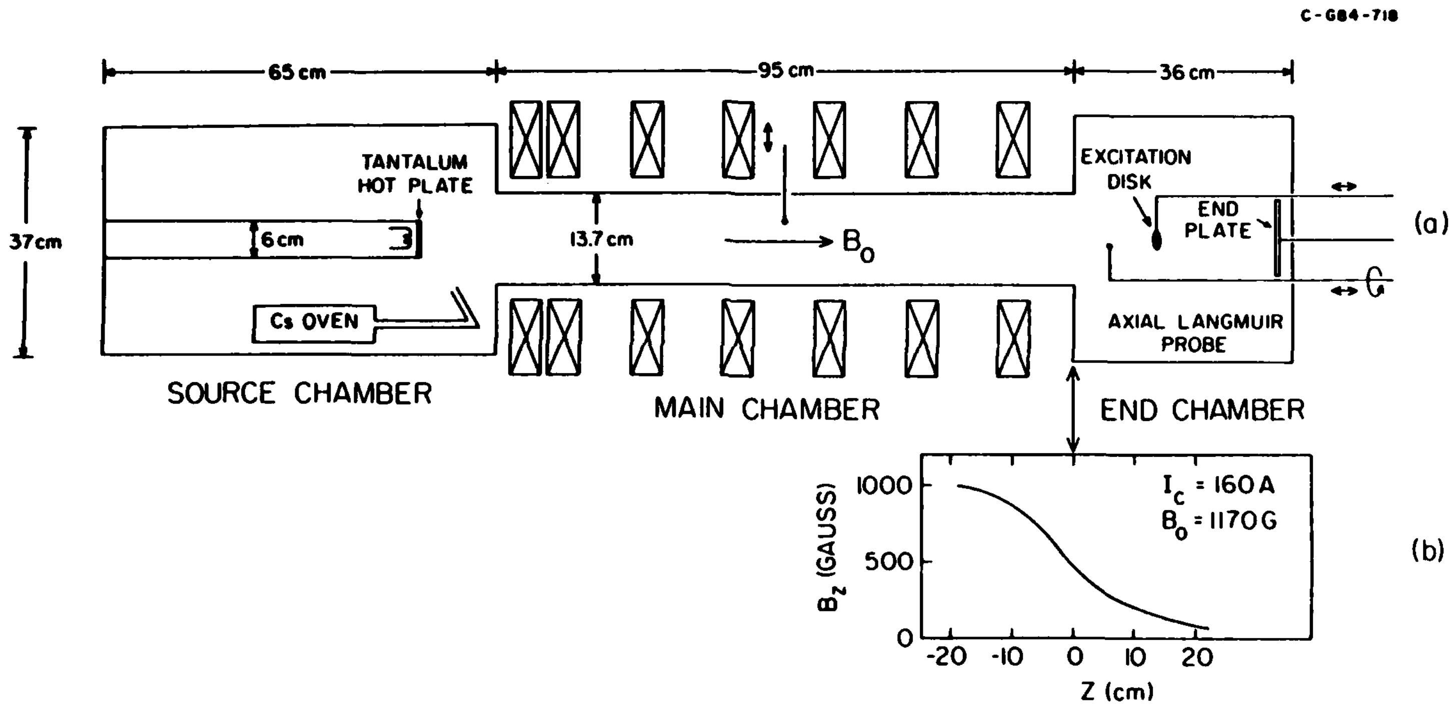
C-G84-718
65 cm
95 cm
36 cm
37cm
TANTALUM
HOT PLATE
6 cm
Cs OVEN
13.7 cm
B0
EXCITATION
DISK
END
PLATE
AXIAL LANGMUIR
PROBE
(a)
SOURCE CHAMBER
MAIN CHAMBER
END CHAMBER
Bz (GAUSS)
1000
500
0
-20
-10
0
10
20
Z (cm)
Ic = 160A
B0 = 1170G
(b)

Fig. 1

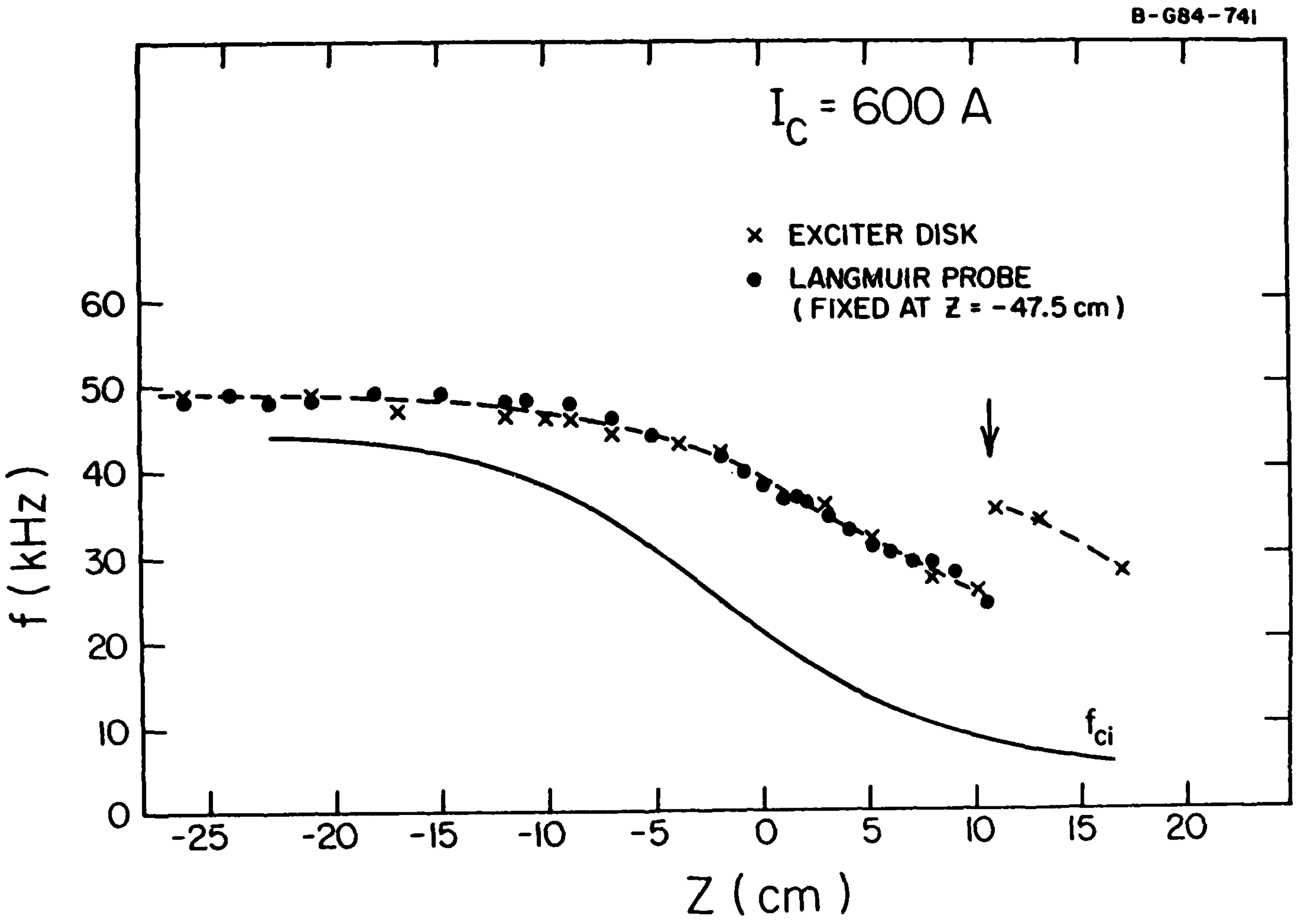
B-G84-741
$I_C = 600$ A
× EXCITER DISK
● LANGMUIR PROBE
(FIXED AT Z = -47.5 cm)
f_{ci}
f (kHz)
60
50
40
30
20
10
0
-25
-20
-15
-10
-5
0
5
10
15
20
Z (cm)

Fig. 2

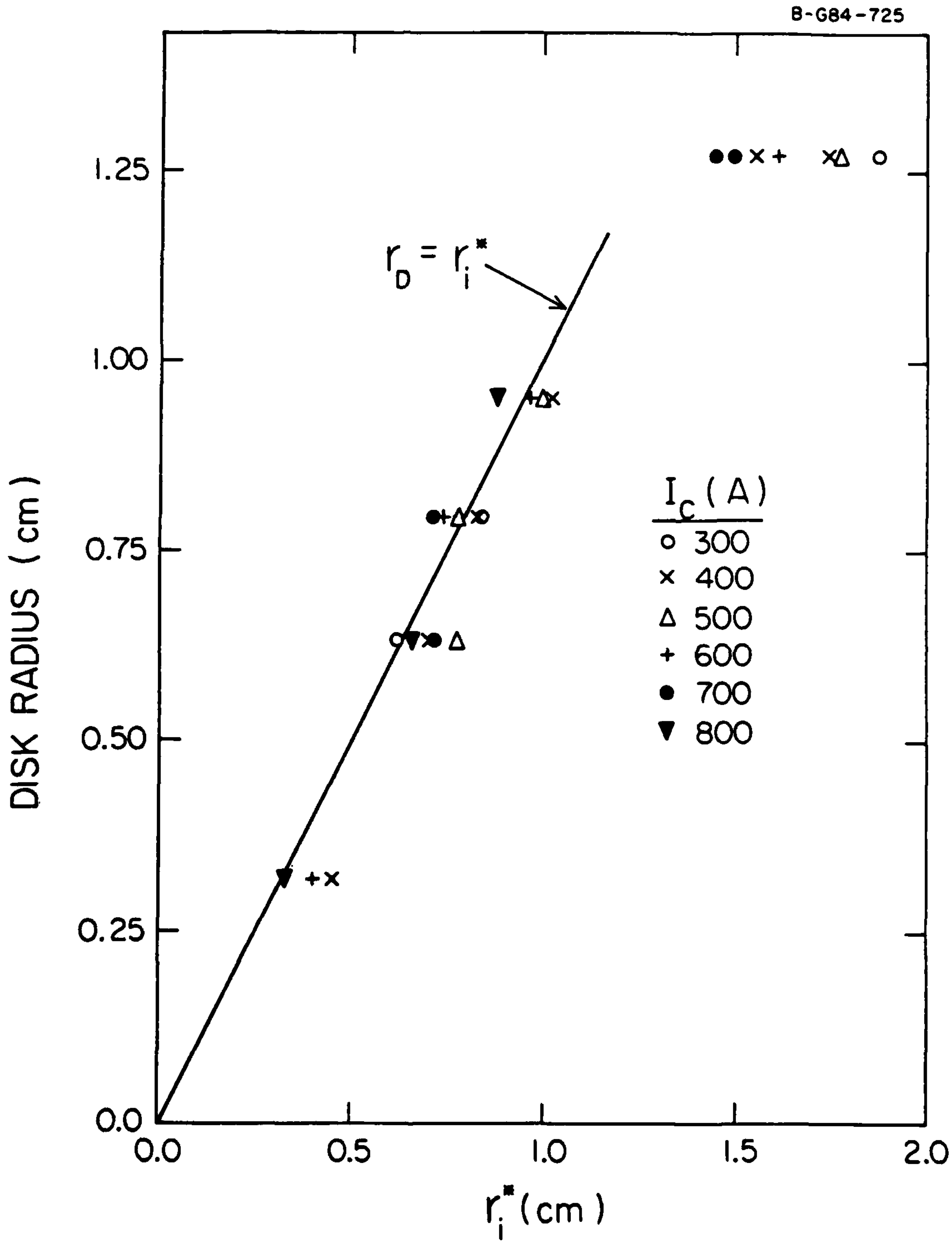
B-G84-725
DISK RADIUS (cm)
r_i^* (cm)
$r_D = r_i^*$
I_c (A)
○ 300
× 400
△ 500
+ 600
● 700
▼ 800
0.0
0.25
0.50
0.75
1.00
1.25
0.5
1.0
1.5
2.0

Fig. 3

END

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